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ABSTRACT

A serendipitous observation resulted in an examination of the effectiveness of using a computer aided design course to improve high school student's strategic reading skills. Conducted in a 3 month semester period, the study relied on teacher observations, student questionnaires, and personal interviews. More than 75% of the students in the computer aided design course improved reading comprehension and study skills. (Contains 11 references.) (Author/RS)

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IMPROVING A STUDENT'S READING COMPREHENSION SKILLS BY TEACHING COMPUTER AIDED DESIGN

A Research Paper

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Abstract

A serendipitous observation resulted in an examination of the effectiveness of using a computer aided design course to improve high school student's strategic reading skills. Conducted in a three month semester period the study relied on teacher observations, student questionnaires and personal interviews. More than seventy-five percent of the students in the computer aided design course improved reading comprehension and study skills.

Introduction

The Computer Aided Design (CAD) course at Notre Dame Preparatory uses a scaffolding instructional format to teach 10th, 11th and 12th grade students the process of designing manufactured objects. Beginning with simple blocks advancing to more complex assemblies to create mechanical drawings using a three dimensional (3D) modeling software package, ProEngineer 2000i2. People see the world in three dimensions and a good design is usually intended to end up as a three dimensional object. Designing in three-dimensions versus two dimensions eliminates the timely corrections and inconsistencies between views or unrealistic geometry. In addition, there are few opportunities for a student to compare the 2D views on the traditional technical drawings with actual three-dimensional shapes found in real life (Bolluyt, 1999).

The series of lessons for our 3D modeling CAD course was originally written as a required twelve-week one-term course for students in the Engineering program at the University of Alberta, Canada (Toogood, 1999). The course is taught at several colleges in the United States as part of the Engineering program, including second year students at M.I.T. At Notre Dame Preparatory each class is forty minutes long and students can stop in the classroom during their study hall period, lunch period, or an hour after school for make-up work or additional computer time. Many students have little experience in drafting design. All have had a course in computer key boarding and many have completed a course in visual basic in their first or second year in high school.

At the end of the semester's Computer Aided Design (CAD) course, many of the students remarked how much the course material helped in improving their reading skills. Several students commented how important it is to read the course material before,

during, and sometimes after performing a computer command function. Students quickly realized that how they read the material directly influenced their success in completing a lesson. It appears they are assessing their knowledge growth relative to the demands of the task while at the same time monitoring their comprehension.

At first appearance, a CAD course would aid and improve visual skills in students. The assumption would be a safe bet. Improving analytical and math skills is an obvious consideration as well. Improving a student's reading skills would appear to be located way down on the list of things learned in a CAD course. The 3D Modeling CAD course improves a student's reading comprehension, strategic reading skills and is having a positive affect on other classes.

In the first semester, a manual is provided to explain the basic operations and design principles involved in creating an object in 3D. There is a list of vocabulary words the student needs to have explained to assist in understanding the concepts of the text, the design and manufacturing process. No text is completely self-explanatory and the instructor assists the student over the hurdles if a first or second reading fails to allow the student to progress satisfactorily. In interpreting the text, the student must draw on his store of knowledge from previous computer classes, the lectures, and a personal research paper. As the lessons progress the student must use knowledge and information learned in previous lessons to complete the required design in new lessons.

During the second semester of CAD closer attention was paid to how a student reads the material to complete each lesson. It is more than "monkey see, monkey do" because the material requires the student to completely understand the lesson before he can complete the later lessons. The lessons progress in an orderly fashion beginning

slowly in small steps. This systematic method follows a scaffold instructional format. As the lessons progress, they become more complex and central ideas are elaborated upon and emphasized in greater detail. Reading the text and following the instructions leads the student to immediately turn written ideas into a visual image.

Many people unfamiliar with CAD see it as a graphic oriented discipline, less reading intensive than, say, an English or history class. Many teachers view CAD as part of the computer sciences or industrial and technical arts curriculum. Schools using the 2D software packages that are an extension of the drafting board using pencils, triangles and T-squares, help perpetuate the concept by placing the design classroom in the part of the building near the wood and metal shop. At Notre Dame Preparatory, the CAD program falls under the math department. Classes are located next to traditional classrooms.

A Review of Reading Research

A key factor that enables students to become successful in understanding the basic principles of the design process is activating their prior knowledge. Borich found that "cognitive psychologists use the term activation to refer to cognitive processes involved in becoming aware of what we have learned and in establishing connections between this prior learning and the task in which we are currently involved" (Borich and Tombari 1997). Activating prior knowledge enables the student to relate knowledge previously learned to new information in the text or class lectures.

In the CAD course different strategies are used in activating prior knowledge. It is important that students have a basic concept of how products can be manufactured in

order to begin using metacognition skills or begins "thinking" design in a CAD class. Methods that enrich activating prior knowledge further a student's appreciation in the reality of the design and manufacturing processes for common everyday products.

Design is a process of connecting points and lines on paper or on a computer monitor that depict a concept or idea. After the lectures students begin to see the world in the points and lines that represent the surfaces of products or machine parts, a building, automobile or artistic sculpture. In an analogy, the student begins to see the world much the same way Thomas Anderson or Neo, played by Keanu Reeves in the movie The Matrix, learns to see the electronic computer generated language, the bits and bites that create the virtual reality images we know as reality. In one of the last scenes of the movie, Neo no longer sees the walls, ceiling or floor of a building quite the same way. Instead, he sees the numbers and data language of the computer program.

To stimulate and add to the student's schemata and grease the wheels of their metacognition during the first week of the CAD classes the student listens to lectures concerning design and manufacturing techniques and methods. Lectures begin with those things that they are familiar. Tissue boxes are disassembled to show how some products begin as blank sheets of cardboard and, using a variety of techniques, are then manipulated into complex creations. Using the tissue box example, lectures illustrate how the box starts as a simple origami design, then how in an assembly process, the cardboard is machine folded eventually looking like those found on the shelves of your local supermarket. Lectures further explain how the same assembly process can be applied to sheet steel to manufacture similar metal objects.

To illustrate how the extrusion process constructs various designed products, like a weather-strip on an automobile door system, the instructor uses children's play dough. Colorful play-dough through a pattern supplied with the children's product. In another illustration, the instructor demonstrates how cupcake utensils and a sandbox bucket filled with wet sand create a mold. Manufacturing uses the mold method to make many plastic and steel products. There are brief discussions using examples of a variety of manufactured products from plastic injection molded or extruded parts to complex welded and machined parts. Car models, still in the box, like the kind we purchase at the model shop, are used to illustrate die making as well as the assembly process. The lectures are designed to activate prior knowledge and make the student aware of the skills and resources needed to create and to design a product.

The design process enhances metacognition skills. According to Baker and Brown, the second component of metacognition is problem solving, planning and evaluating effectiveness (Baker and Brown, 1984). These components to metacognition are innate to the design process. Designs created to solve a problem are usually to fulfill a need or to perform a function of some kind then evaluated for effectiveness in fulfilling the need or function and how well it solves a particular problem. The part or product designed by the student can be tested and evaluated relatively quickly. Geometry defines the three-dimensional model and the uniqueness of the software allows addition of material properties to further analyze the model. For more advanced CAD courses, animation is used in the design and a student can evaluate a performance model, see the contours of the Von Mises stress and magnitude of the design's deformation (Toogood, 1999). A 3D printer allows inexpensive prototype construction. A 3D printer creates

plastic prototype models using plastic resin material and a laser. All of the evaluation, planning and problem solving involved in the design creation process are opportunities that help improve a student's metacognition.

In the CAD classroom the student learns self-monitoring skills quickly.

> "Metacomprehension functions when the student realizes whether he does or does not understand what he is reading. When the student is conscious of his own thinking and comprehension, he tries different strategies if comprehension breaks down. A student who has well-developed metacognitive skills is more likely to be an independent reader (Roe, Stoodt and Burns, 1998)."

The software package ProEngineer 2000i version 1 & 2 tutorial reacts quickly to mistakes in understanding. Designs will not generate in 3D if a student fails to understand directions during the sketcher portion of the design creation. Mistakes in understanding or failing to comprehend the instructions force the student to find other solutions or seek additional support mechanisms to complete the design. The student must then reread the text, engage in cooperative learning, ask for instructor support or find another way to fix the problem.

A CAD student quickly analyzes what strategies work best by trial and error because results are immediate. A student indirectly learns to be a strategic reader to successfully complete the course because of the immediate responsive nature of the software. The student quickly learns to read the information in the text first searching out important new ideas and instructions as well as focusing on knowledge the lesson assumes he has learned previously. The student constantly relates new knowledge to

prior learned knowledge. He must mentally sequence prior learned information looking for distinct changes in the pattern of specific operational commands. If he is correct in understanding the information, the computer allows him to create the object immediately. If incorrect, the design fails, requiring the student to reread, skim or summarize the steps to become successful.

Learning the design process coupled with deadlines for a design or lesson completion forces the student to improve his reading strategies. As lessons progress, a student quickly sheds poor learning strategies and adopts those strategies that have proven more successful-remedying comprehension failures on his own.

The student needs to understand the reason for learning. Sometimes teachers forget to communicate information without explaining the relevancy of the knowledge. This applies to reading as well. A student learns best when he understands the objective and purpose for reading. When he understands this relationship and the relevance of reading, his life becomes clearer and he will invest greater energy and will increase comprehension (Adams, Gullotta, and Markstrom-Adams, 1994).

In the private sector, job descriptions or the mastery of specific tasks within an occupation are sometimes broken down to specific skill levels. A master machinist compared to an apprentice or a police officer compared to his sergeant or Detective, a Masters degree compared to a Doctorate of Philosophy, have pre-specified standards or goals that places them differently in a hierarchical skill level structure. Most people understand objectives and the purpose for goals. An employer retained to design or to manufacture a product meeting specific criteria by a specified date understands the objective and deadlines before he agrees to the contract. Best illustrated in the military

model the importance of objectives, goals and standards is a critical element in soldier training strategy. In the military skill process, clearly defined, identified mission essential tasks are broken down into sub-tasks. These subtasks identify critical training standards performed by either an individual soldier or his unit before they can move on to difficult tasks of greater complexity. Soldiers must train to meet or exceed clearly defined written and explicit standards. Soldiers who fail to meet the standard, goals or objectives, are retrained and retested. Individual soldiers and military units from squad size to battalion size take as much time as reasonably necessary to train to standards. An employer with a contract, a soldier with a mission or a student with a lesson, needs to understand the standards that determine success as well as the objectives and goals to fully accept, appreciate or engage in the learning process.

Much research on critical reading strategies is available and most focus and agree on seven basic concepts. Learning about the text before reading it involves previewing the information. Previewing the text increases comprehension by enabling the reader to obtain a sense of what the text is about and how the text is organized. Reading previews before reading short stories increases a student's learning. Previewing alerts students to key points and important details. The CAD course CD ROM tutorial allows the student to preview.

To further illustrate and expand the student's knowledge of the design and manufacturing process, the student is required to seek out common everyday products and research manufacturing methods and write about it in a short research paper. The research paper represents thirty-percent of the final grade and is submitted in three stages beginning with a rough draft, a revised copy and a final edited version. Accuracy,

grammar and composition as well as adherence to MLA style are graded. Publishing the student's research paper for use by future classes after grading inspires the student to improve their quality. [1]

Research on schema theory and prior knowledge has clearly shown that the student's construct meaning by using his prior knowledge to connect and understand new information. The children's play-dough toy and writing of the research paper help to activate the student's prior knowledge. Publishing the work for use by future students of the class develops self-esteem and helps to expand his schema. He soon sees the world differently and begins to appreciate what it takes to create.

Research has shown there are many varied strategies that effectively improve reading comprehension. A concept grown out of this research called scaffolding is based on the ideas that at the beginning of learning the student needs a great deal of support and gradually this support is removed to allow the student to try his independence. The gradual release of responsibility allows the student to achieve success and bolster self-esteem. The instructor is the support system when failure seems likely. Support is continually applied until the student achieves success.

The CD ROM presentations follow and give further insight to the text material. The instructor is the support system stepping in to assist students over major obstacles or through the few areas the text and CD ROM differ or are not clear. In many cases, the instructor can quickly ascertain the causes of the problem. The instructor points out and corrects any inconsistencies between text and software at the beginning of each lesson. In other cases, the instructor quickly realizes the student fails to fully comprehend a few

[1] The original idea in publishing student's work came from Angela M. Conner's article "Motivating middle school students to revise and edit," published in the high school edition of the English Journal, Vol. 90, Issue 1; Urbana; Sep 2000.

key points in previous lessons or in the particular lesson he is working on. The instructor redirects the student back to those lessons to reread and relearn the material. This allows the student to realize his mistake on his own. In other examples, past experience tells the instructor poor performance on a lesson is a direct result of the student's failure to fully comprehend and follow the directions in the text workbook for that particular lesson. Rather than take the ten or more minutes to discover the student's exact error the student must reread the material. Forcing the student to reread the lesson instructions may seem cold and heartless to the student; however, the thoughts quickly disappear when the student discovers his error or misunderstanding. The student soon realizes it was because he failed to read and understand all the material in the lesson and not the fault of the software, CD ROM Instructions or text. He also realizes quickly that mistakes are inevitable. Mistakes and are not punished by the receipt of a poor grade. Instead, mistakes become part of the learning process and an integral part of the road to success.

To evaluate each student the instructor uses reality-based methods of evaluation for a final grade on each lesson. Many designers in the working world have technical skill and behavior as well as many other desirable attributes evaluated on a regular basis. During the introduction phase of the course, the student learns that evaluation is similar to an engineering department's evaluation of workers. If the student is self-motivated and gets projects done on time, they receive rewards like a pay increase. Grades take the place of financial rewards in the classroom setting. Those that are less motivated and fail to get the projects done by the client's deadline receive a lesser grade. Completed projects before the deadline or on time receive an "A" grade. If a student is one day late, he receives a "B" grade, two days late, a "C" grade and so on. A completed lesson,

checked for accuracy, must follow the design intent as well as meet the lesson's specifications. Details are important. Incomplete or partial assignments are not acceptable. The course requires that the student become self-motivated enough to complete the lessons. The lessons are fast-paced and varied and become increasingly more complex and difficult. There are reasonable deadlines for each lesson to insure every student to be successful if he is diligent in his effort. Deadlines can be adjusted as well. If the entire class has difficulty in meeting the deadlines, the instructor pretends to call the client and requests additional time. Time is extended ff the class exhibits diligent effort.

A team approach to handle the more difficult lessons is strongly encouraged. Students often work together in groups overcoming problems and discovering solutions to mistakes or misunderstandings in the material. Students are free to ask fellow students for assistance.

A different student can experience the same type of problem the instructor handled early in the course with another student. This experience allows the instructor to quickly troubleshoot student concerns. The instructor develops a mental checklist of possible solutions to a particular student design problem and often forces the student to reread the material rather than spent valuable class time retracing the steps. Allowing the student to rethink and reread the text or suggesting they review the CD ROM tutorial again to discover the solution saves time. The instructor steps in to assist the student only if all the other avenues to solve or answer the question are exhausted.

A key factor in teaching is using multiple tools of technology to stimulate learning. Some students thrive in lectures; others obtain information from reading text

material. In our modern high tech society, teachers must compete with computers, fast paced television programs and video games. Reading is no longer the source of knowledge it was before the technological revolution. An increasing number of students seem to learn best through visual media such as diagrams, illustrations and various forms of video technology, including Powerpoint presentations, video documentaries, various video games and interactive software. According to Anne Meyer, co-director of the Center for Applied Special Technology (CAST), "educational research indicates that more options for expression, including artwork, photography, drama, music, animation and video, open doors for a greater number of students to successfully communicate ideas, knowledge gained, and talents. This applies to students with particular skills and proclivities as well as to students with disabilities that prevent them from using certain media effectively or at all."

Software or other technology that offers recording and playback such as a school run publication, video production or a radio theater course enables students to compose, analyze and revise the work before submitting a final product. In a discussion with a seventh grade composition class at Marist Academy the students found rewriting the traditional Christmas Holiday poem "The Night Before Christmas" into a modern version with Santa arriving on a Harley motor cycle rather than reindeer and sleigh, then recording it, complete with sound effects, as an enjoyable segment of the class. Writing the modern version was fun according to most of the students. Reading and comprehending the poem is a key factor in rewriting.

In the personal interview with the students, they mentioned reading as one of the least favorite activities. They often expressed it as boring and slow. Most alarming were

the "I hate to read" comments. If we look closer at the student's reading activity, however, it is obvious that the student does not "hate" to read. Instead, it is the reading material that they must read on occasion to learn information for a class where they have the lack of interest. Many of the students who expressed an aversion to reading were often observed reading about the school sports progress on the student run Internet site. The CAD course manual viewed differently from the "I hate to read" material and was obvious to the instructor. The student finds generating designs using CAD software as enjoyable as the 7th grade composition class enjoyed reading, rewriting and acting out holiday stories and poems for a radio theater program.

Reviewed software that is specifically designed to improve a student's reading and comprehension skills is electronic extensions of a text or workbook, nothing more. The interaction between student and the electronic media device is the testing format, limited to making the appropriate selection by clicking the answer, rather than circling, checking or filling in the circle on a data card with a number two pencil, from a list of multiple choice answers and receiving an immediate response from the computer, rather than a teacher.[2]

Research Design

How well does this course help student reading and do they realize that reading comprehension is improving? Each student in all four classes, seventy-five students answered a short questionnaire specifically prepared to discover what it was the students did to achieve success in the course. To avoid giving away the intent of the research the

[2] Reviewed Reading Comprehension Improvement software includes Merit Software for Advanced Students (Grades 8-11) found online at www.meritsoftware.com and Reading, Education and Attention for Dyslexics, Inc. found online at www.literature2001.org.

questions varied and did not specifically pertain to the reading activity. Only those questions that specifically pertained to the reading and learning activity are for this research study. To learn additional detailed information short personal interviews conducted with approximately twenty students. How often they referred to previous lessons and or reread sentences and paragraphs during an average lesson was especially important.

Results

In the essay responses to the questionnaire more than seventy-five percent of the students described that they often referred back to previous lessons to correct mistakes or to refresh their memory, and often reread sentences to understand the directions correctly. Each student worked with or asked for assistance from fellow students (cooperative learning). The last question asked was "When you discover you made a mistake what do you think most often caused the mistake?" The most common response was what can best be summed up in one student's words: "I failed to read and fully comprehend the text information."

After mastering many of the lessons, the student often investigated the limitless potential of the software venturing into areas not in the lessons. They are inspired to seek out new information, try different techniques and strategies to perform basic functions. The classroom carries five different manuals relating to the design software and the students regularly use them during a study hall period or lunch break.

Students learn to read the material and think about what it takes to achieve success by having meaningful engagements with more experienced students. Students

learn at different speeds, and students working at a particular point in the lesson tend to gravitate together in a team effort or form a cooperative learning relationship to work out problems to assist one another in understanding the material. In many situations, the quicker learners assist fellow students who are having difficulty. In two cases, there were limits to what experienced students did to help fellow students. There is an element of peer pressure to complete individual lessons that soon develops within the classroom. Students learn which of their fellow classmates are motivated, and those who are not. A student's failure to read and understand a lesson forces him to constantly ask other students for assistance. This process becomes annoying to the class and slows individual progress. A give and take relationship develops among students who are progressing. If a student sees little benefit in helping another student who may not be able to give back assistance in that or later lessons, he is reluctant to give continual assistance because it may jeopardize meeting his deadline objective to achieve a good grade. Fellow students or otherwise mimic the teacher in a blunt tone to read the text often politely ostracizes students habitually asking for assistance. Within a few classes unmotivated students notice the hint and begin working, if somewhat reluctantly.

By the second month of the course, the teacher discovered that in at least one case, a student had a problem reading and comprehending the material. He was below average in all his other classes as well. He used his study hall period to catch up on his CAD lessons. The instructor worked closely with the student reemphasizing the comprehension strategies other students are using to learn the material offering suggestions that he try the same strategies in his other classes. Rereading and looking back over the material as well as reviewing previous material seems to be working. By

the third month of classes the student caught up and earned a bonus in the process by improving his grades in his other courses. Two teachers confirmed the improvement.

Students having difficulty finishing the design discover it is because they tried a short cut to get through the lesson. By lesson number three, students quickly learn that using short cuts in their reading strategy results in incomplete or poor results. Simply reading the instructions once is often not sufficient to properly complete a lesson. To properly complete the lesson on time and correctly, they must employ the methods of a good strategic reader.

Students, told at the start of the course that short cuts or cheating quickly catches up with them and is more obvious in CAD than it may be in other classes. Interestingly, the personality of ProEngineer software will not allow a student to complete the design if he does not perform specific command functions correctly and in sequence. Those students who choose to cheat by copying and using another student's finished lesson are quickly discouraged in lesson three and four. By nature of the course, students go back to the previous lessons to relearn and review the previous material to complete the present lesson. Students quickly learn that competency, speed and accuracy are best achieved by reading and rereading the material the old fashion way.

Lesson six in the text is unique because it requires a student to read ahead for clarification to successfully complete the design problem. If he fails to read ahead within minutes, he will become frustrated and will ask the instructor for assistance. The instructor tells the student to simply turn the page and read on. It is humorous to witness the cooperative learning taking place and at the same time witness its absence when

students sitting next to one another have the same problem at different times in the same class period.

"Engaging students to learn includes building their confidence and arousing their interest, enthusiasm and desire to learn. Motivating students to learn may be the most challenging aspect of teaching and instruction" (Meyer, 2001). Using the 3D Modeling CAD software the student can become so heavily engaged in the lesson that he almost seems to be encased in a sound proof bubble. Students appear directly wired to the text and computer. For other students, the school's public address system or instructor's announcements, or even the bell sounding the end of the period is a nuisance to their task, an unwelcome hindrance. On occasion, teachers complain about sleepers, the clock-watchers, and bored or talkative students. Such is not the case in the CAD course. Rather, the opposite is true. It is refreshing to hear students complain that they must turn off the computer and leave the classroom at the end of the hour.

Several students in each of the four classes appeared to be lessons ahead of the average student. In closer examination and during the personal interview that the majority of the students who were out-performing their fellow classmates used variations of the Circle, Underline, Count, Check (CUCC) strategy to organize thoughts. Many students circle key direction words and underline the information that goes with the direction word in the text. Still others included numbering (count) each direction word or key direction sentence to organize the sequence of steps to perform the function before beginning the lesson. The student checks and verifies the information by rewriting it, using the numbering system, in their personal notebook.

Conclusion

In the CAD course the student will quickly understand that a successful outcome is directly related to understanding the reading material (self-evaluation of comprehension). That reading is a required part of learning the operation of the software as well as the design process. It is evident that the students developed and improved reading strategies to accomplish and achieve success in the course with lessons that reflect obvious connections from the text to application of the established purpose for reading. The CAD course engages the student in reading context based material and greatly improves reading comprehension in the context of course work, more so than the software reviewed that is specifically designed for "reading comprehension improvement" which seemed to be nothing more than pages and tests on a video screen. The 3D modeling CAD course is more than pages on a screen. It is an interactive engaging puzzle and a tool to fulfill a basic desire to create. It is unique in that words and thoughts are manipulated into something different, a three-dimensional object.

How much improvement each student makes in reading comprehension and how much is carried over into other subjects are difficult questions and cannot be measured in such a short research period.

The software stretches the teachers ability to quickly teach in that it has a built-in punishment and reward system, unique to the ProEngineer CAD program software, allowing a design creation only if the student comprehends the instructions and follows directions correctly. Both success and failure is immediate and tied to reading and comprehension of the information. The student does not need to wait days for the test results to realize if the learning strategy they are using is adequate or not. Failures are

immediately corrected on a regular basis. Teaching CAD is an excellent tool to improve a student's reading comprehension skills.

The positive implications and excellent potential for improving a student's reading comprehension using a 3D Modeling CAD program should not be underestimated. Selected first year high school students with reading difficulties might benefit from a slower paced introductory CAD course with more emphasis on improving reading comprehension skills as opposed to learning design and the software. Not only will a student benefit from these strategies, but school administrators, counselors and parents should see a marked improvement in study habits of challenged students. A noticeable improvement in understanding of new material and ultimately, higher test scores and grades can be achieved.

This coming fall an advanced 3D CAD class is on schedule for those students who completed the introduction course. There will be changes in the introduction course after the student completes the first text lesson. Rather than allow the student to discover the learning strategies on their own, two class periods will be scheduled to teach the reading strategies. Teaching the strategies will speed up the learning curve of the slower student as well as confirm the process for success for that student already using the strategies.

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